"Detecting Dark Matter Via Atmospheric Cherenkov Telescope Arrays"

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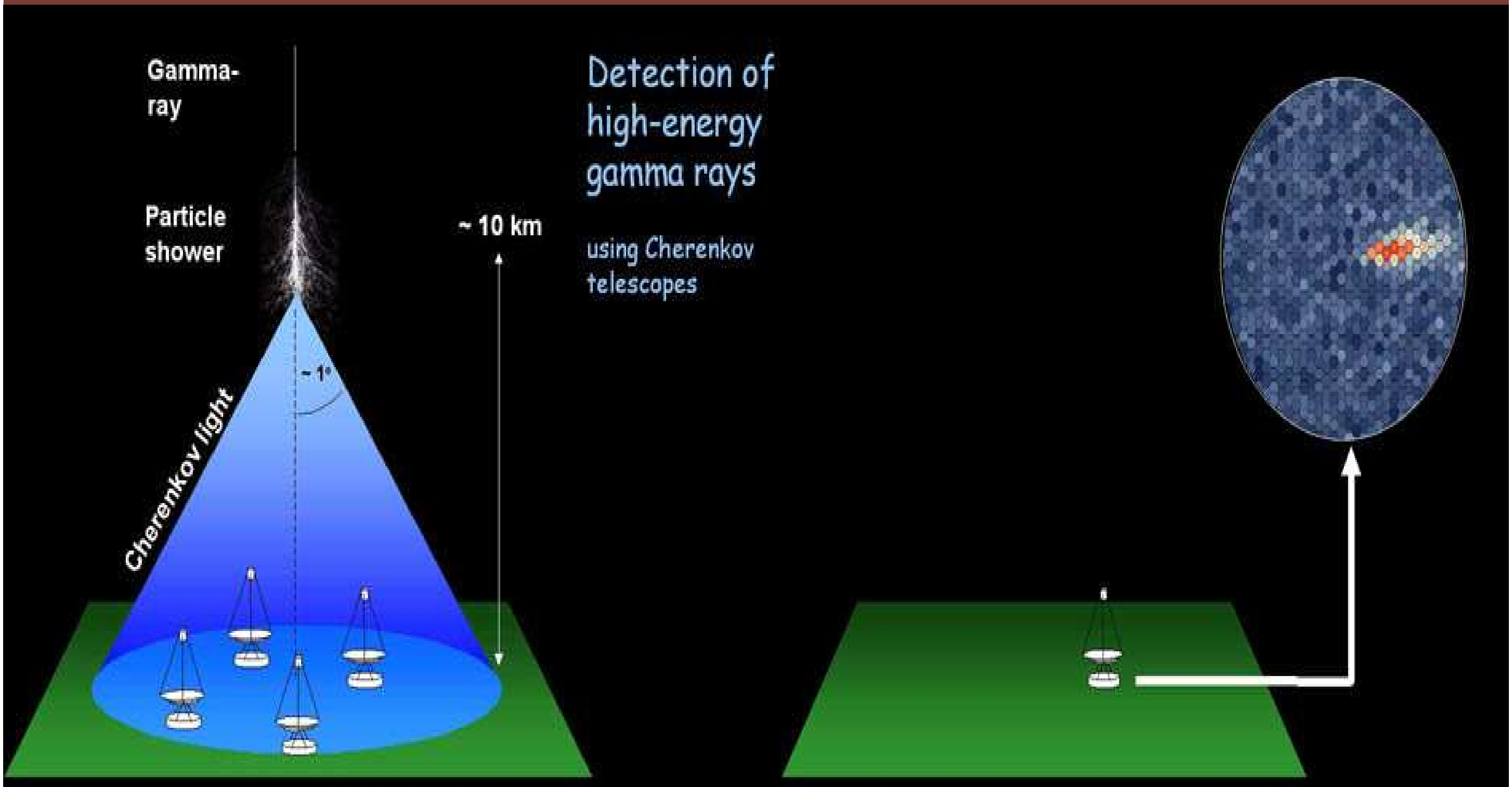
Based on *Tasitsiomi and Olinto, astro-ph/0206040*

The Question

- *Assuming that dark matter is annihilating neutralinos, whose annihilation -- among other products -- yields continuum and monochromatic gamma-rays: will we be able to detect dark matter via the upcoming atmospheric Cherenkov telescope (ACT) arrays such as CANGAROO-III, HESS, and VERITAS ?*

Ground-based Gamma Ray Astronomy: Acts & ACT Arrays



ACT Arrays

- Typical technical characteristics (having VERITAS in mind):

  Energy range: 50GeV-50TeV

  Effective area : ~10^8 cm^2 at E~100 GeV

  ~10^9 cm^2 at E~1 TeV

  Angular resolution : 5' at E~100 GeV

  2' at E~1 TeV

  Energy resolution : 15%

- Examples: *CANGAROO-III, HESS, MAGIC, VERITAS (2003-2005)*

Where to Look for DM?

$$Flux \propto \frac{\langle \sigma v \rangle}{m_\chi^2} \frac{\int \rho_\chi^2 dV}{d^2}$$

as close as possible, as dense as Possible

Galactic center (Berezinsky et al. 1992, 1994, Bergstrom et al. 1999, Gondolo et al. 1999, Gondolo 2000, Bertone et al. 2001, etc.)

substructure (DM clumps)

- Lower the backgrounds as much as possible

DM clumps in the Galactic halo!

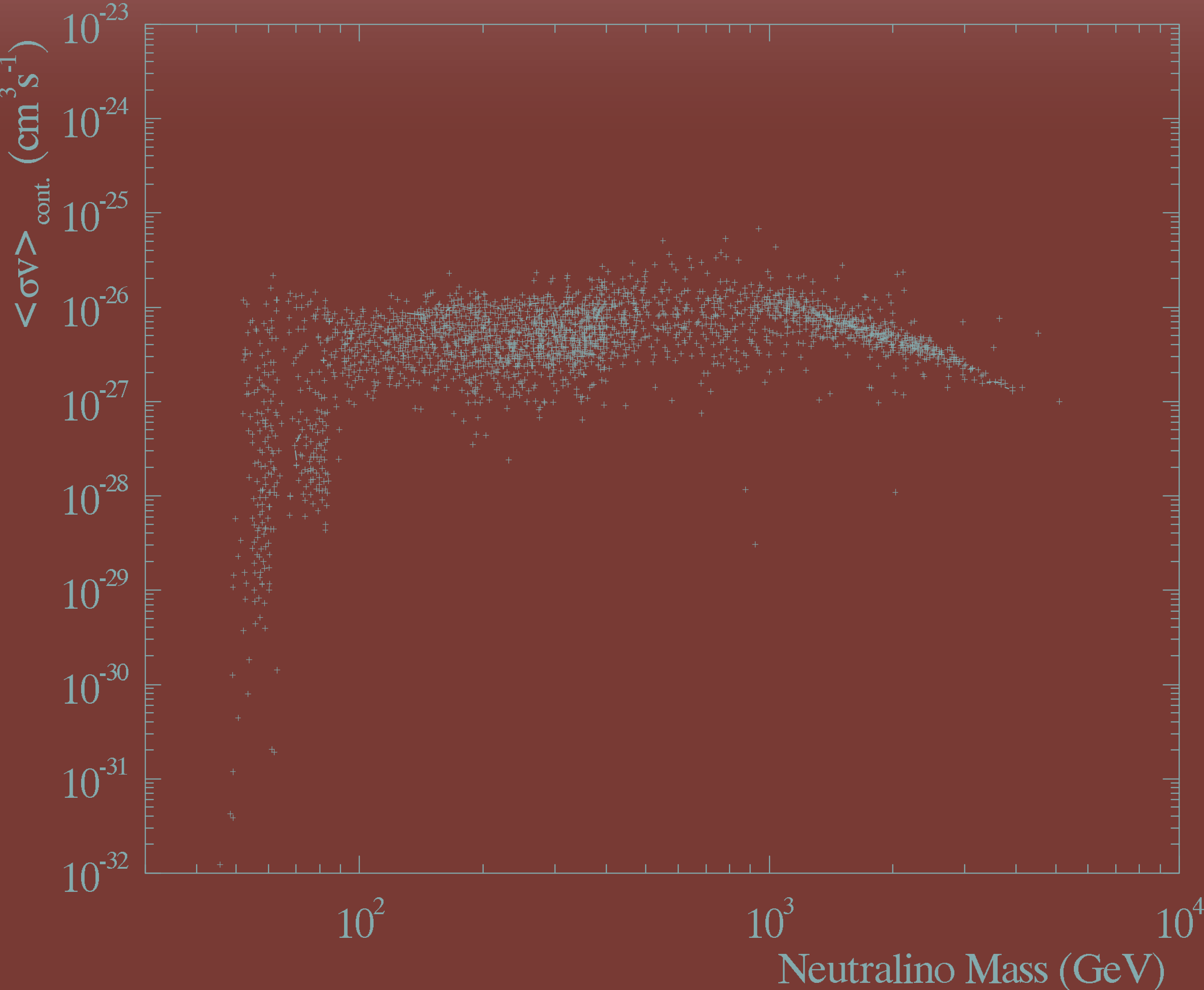
We need:

$$Flux \propto \frac{\langle \sigma v \rangle}{m_\chi^2} \frac{\int \rho_\chi^2 dV}{d^2}$$

- the distance of the clump, d :N-body simulations

- the density profile of the clump, ρ_χ :SIS $\propto r^{-2}$
  :Moore et al. $\propto r^{-1.5}$
  :NFW $\propto r^{-1}$

- the SUSY parameter space, $\frac{\langle \sigma v \rangle}{m_\chi^2}$



$\langle \sigma v \rangle_{cont.}$ (cm^3 s^{-1})
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
10^2
10^3
10^4
Neutralino Mass (GeV)

The Backgrounds

- The dominant contributions:

Electronic showers :

$$\frac{dN_{e-}}{d\Omega}(E > E_o) = 3.0 \times 10^{-2} \left(\frac{E_o}{1GeV} \right)^{-2.3} cm^{-2} s^{-1} sr^{-1}$$

Hadronic showers :

$$\frac{dN_{h}}{d\Omega}(E > E_o) = 6.1 \times 10^{-3} \left(\frac{E_o}{1GeV} \right)^{-1.7} cm^{-2} s^{-1} sr^{-1}$$

Results: The Detectability Condition

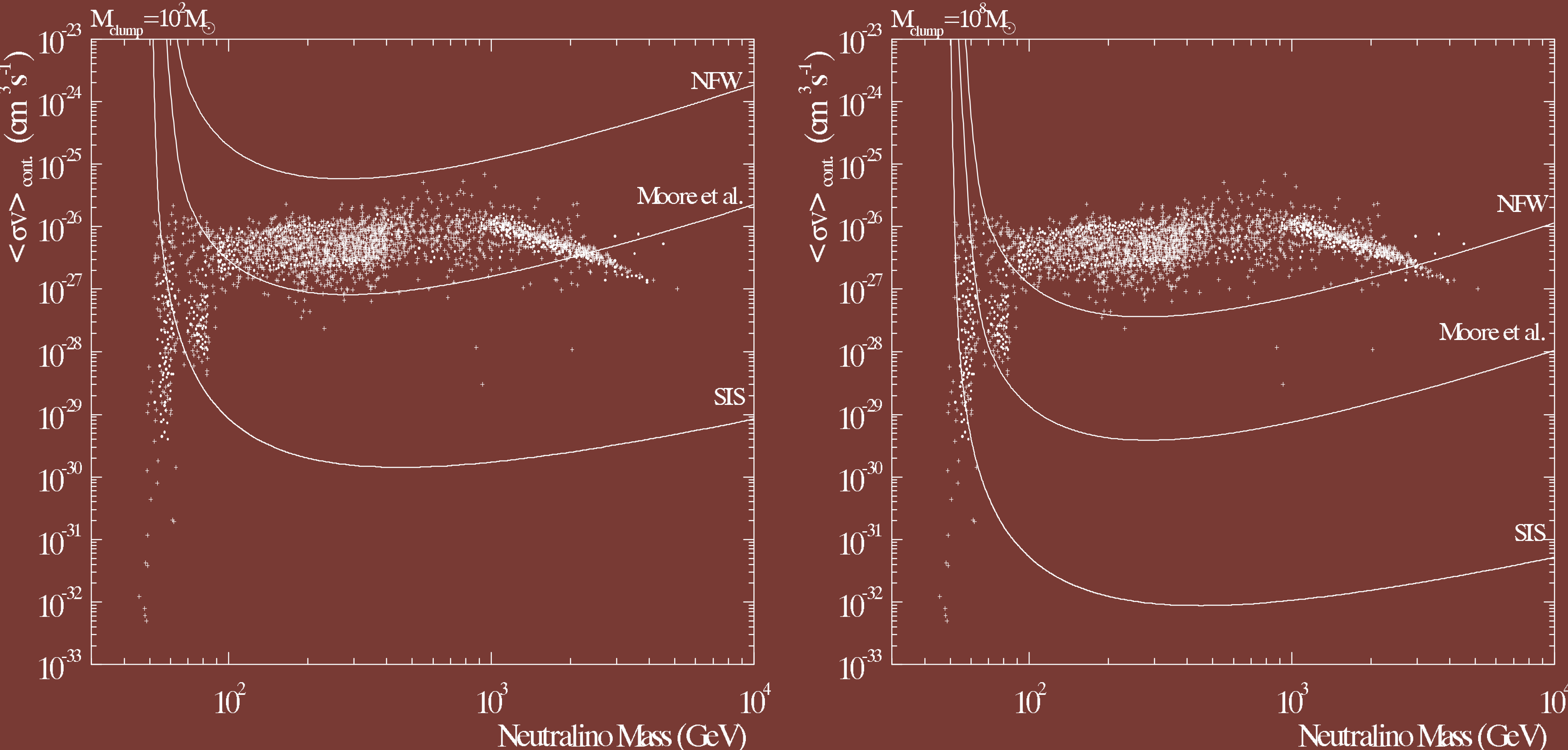
The conditions:

$$S = \frac{N_s}{\sqrt{N_b}} \geq M_s$$

$$\langle \sigma v \rangle_i \geq g\left(I, Aeff, t, d, \frac{dN_{bgi}}{d\Omega}, \Delta\Omega, M_s, E_{th}\right) \times m_\chi^2 / N_{\gamma i}$$

The study of the detectability of DM in clumps is tied to the lack of knowledge of the SUSY parameters: inevitably, the results with respect to the DM detectability by ACT arrays takes the form of constraints on the SUSY parameter space.

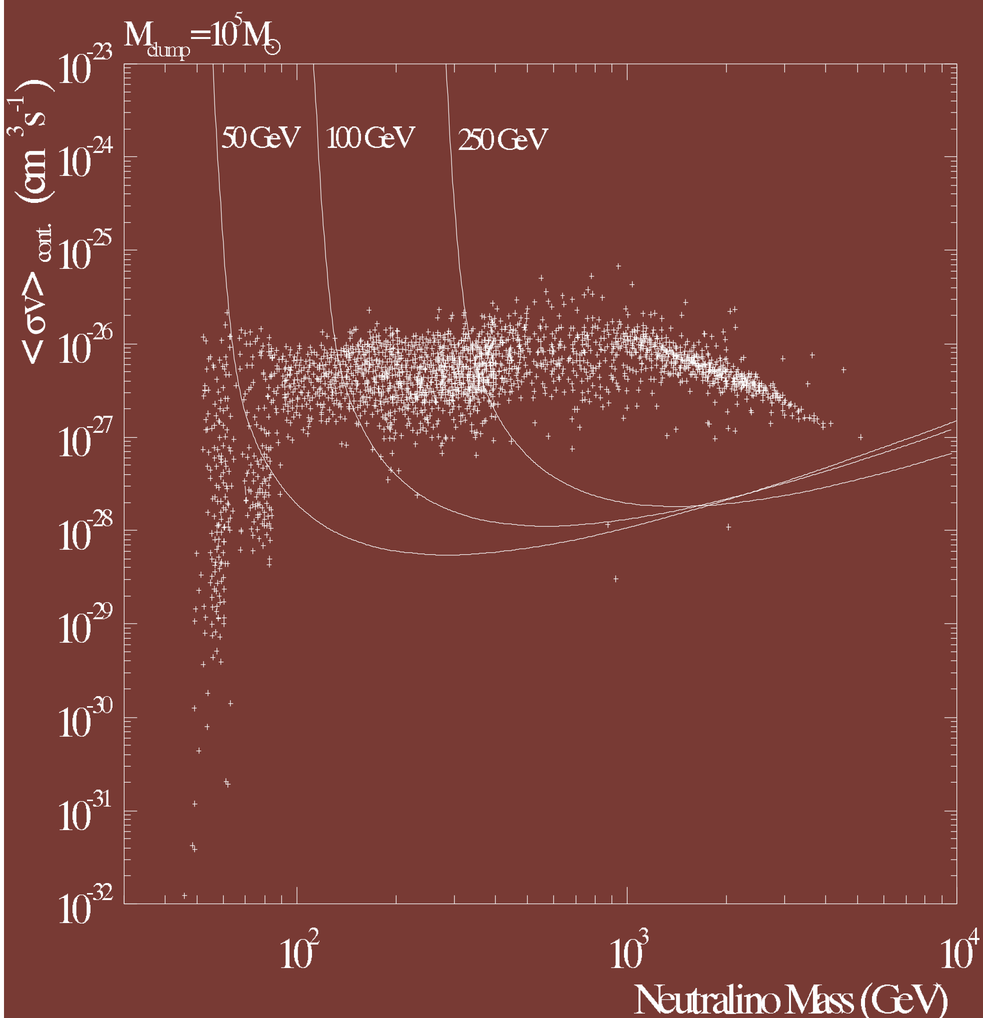
5-σ detection in the Continuum: 50Gev, $10^8 cm^2$, 6 ʹ ,100 hrs



-SIS is detectable, unless $m_\chi \leq 70$ GeV
-Moore has good chances
-NFW not detectable: it does not provide any constraints

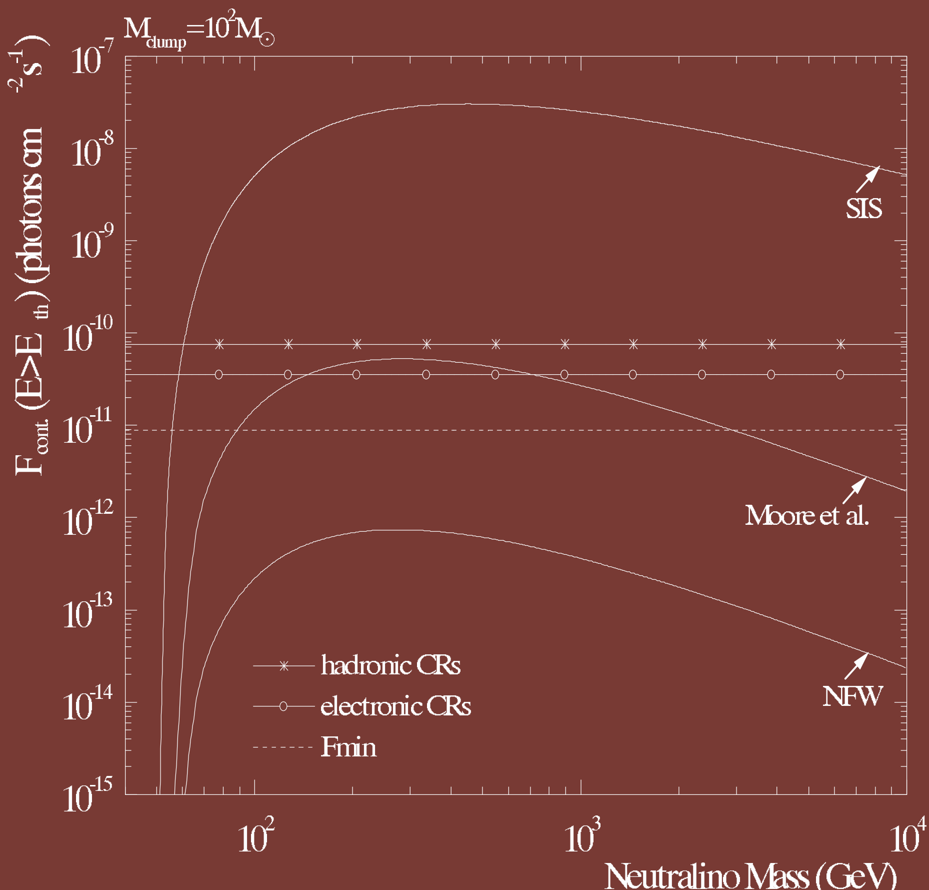
-For high clump mass the NFW has good detectability
-6 orders of mag. higher clump mass,
2 orders of magnitude lower cross section + access to smaller m_χ

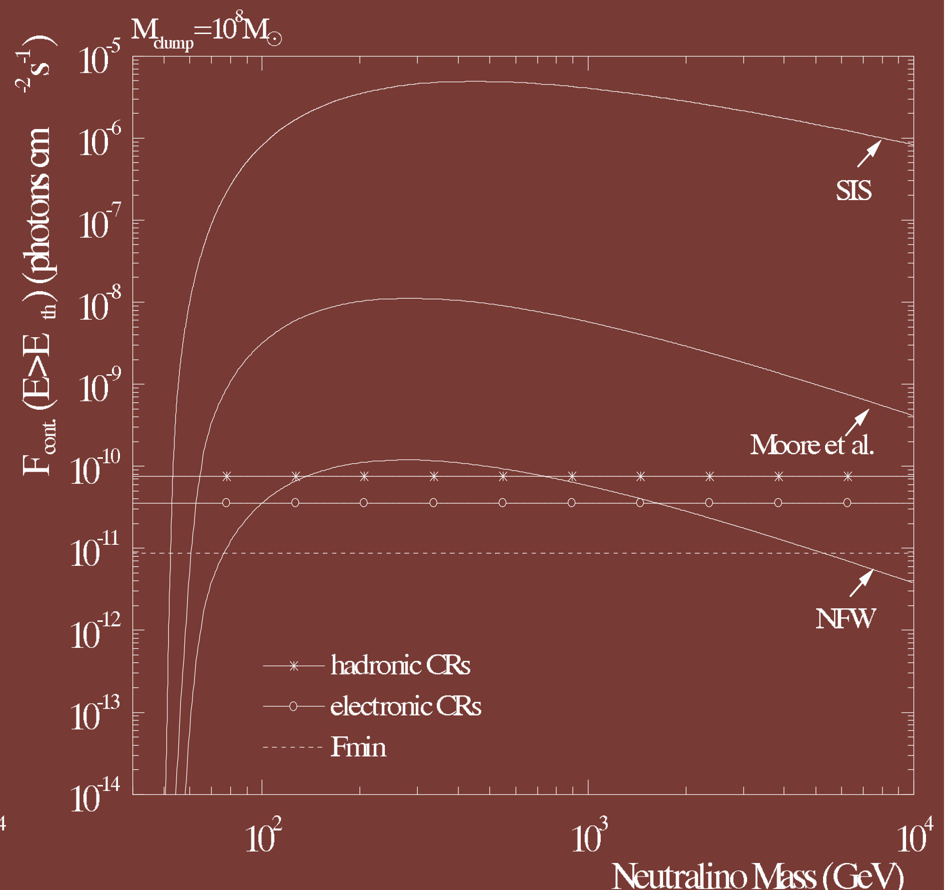
5-σ detection in the Continuum: $10^8\,cm^2$, 6 ' ,100 hrs, Moore et al. for 50 GeV, 100 GeV, 250 GeV



- Higher E_{th} → larger A_{eff}, better ang. resolution, lower backgrounds
- Lower E_{th} → larger part of SUSY p. space can be explored by ACTs (trivial but important)
- Important to explore the low m_χ region → complementary observations at lower energies via, e.g., GLAST, accelerators, direct searches

5-σ detection in the Continuum: 50Gev, $10^8 cm^2$, 6 ʹ ,100 hrs, $\langle\sigma v\rangle_{typ} = 5\times10^{-27} cm^3 s^{-1}$

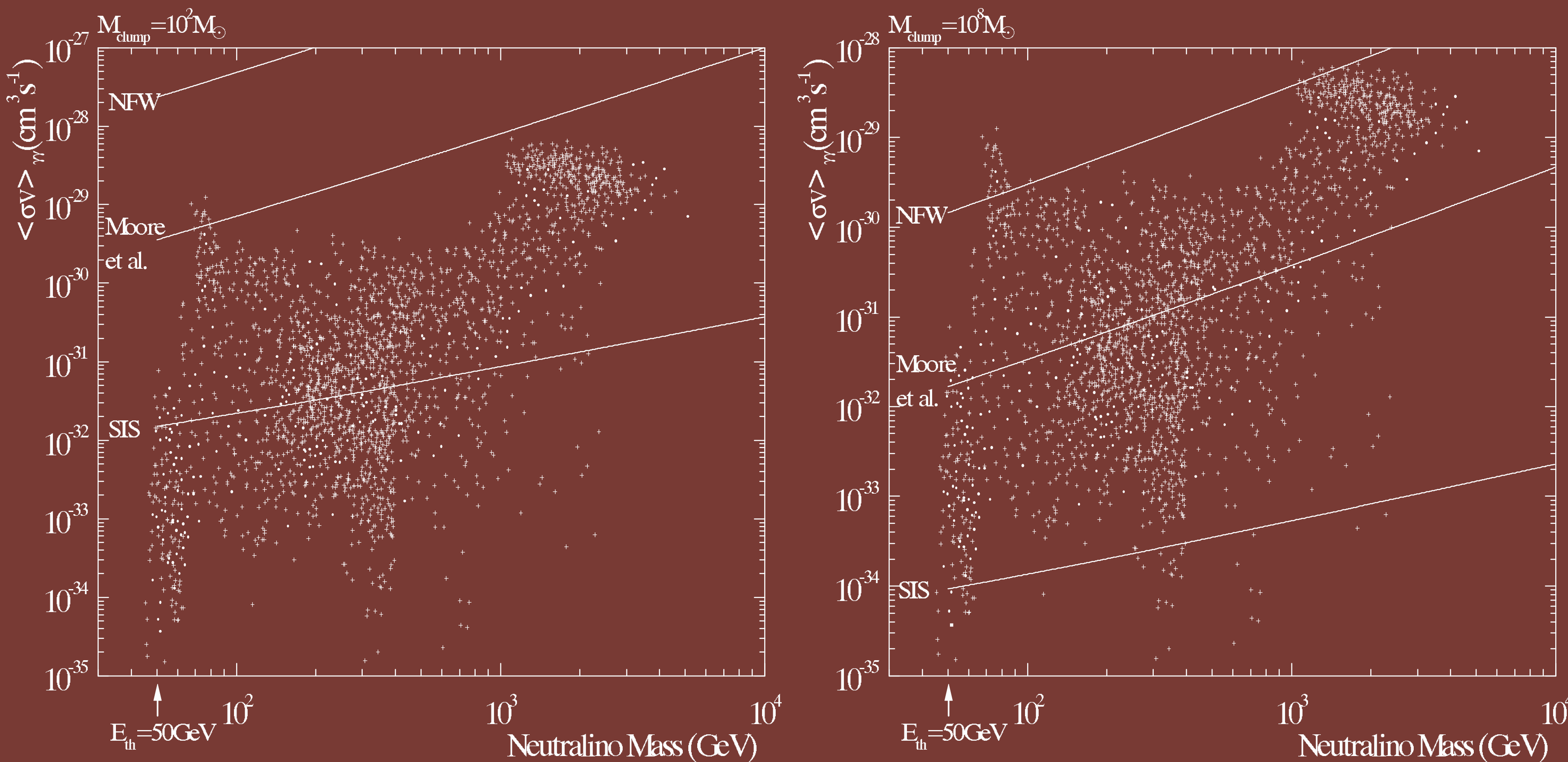




-SIS detectable for $m_\chi \geq 55$ GeV
-Moore detectable for 87 GeV $\leq m_\chi \leq$ 2.9 TeV
-NFW not detectable

-SIS detectable for $m_\chi \geq 53$ GeV
-Moore detectable for $m_\chi \geq 65$ GeV
-NFW detectable for 77 GeV $\leq m_\chi \leq$ 5 TeV

5-σ detection in the γγ-line : 50 GeV, 10^8 cm^2, 6 ‘ ,100 hrs, 15% (energy resolution)



- The m_χ - $<\sigma v>_{\gamma\gamma}$ SUSY parameter space is considerably more extended with respect to the cross section than the m_χ - $<\sigma v>_{continuum}$ parameter space
- Bad line detectability
- Similar for Zγ-line

Discussion: Combining Observations

- continuum $\rightarrow m_\chi \in [m_{min}, m_{max}]$ or $m_\chi \geq m'_{min}$
  lines $\rightarrow m_\chi \leq m'_{max}$

e.g., a 10^8 $M_\odot$ *Moore et al. clump is detectable in:*

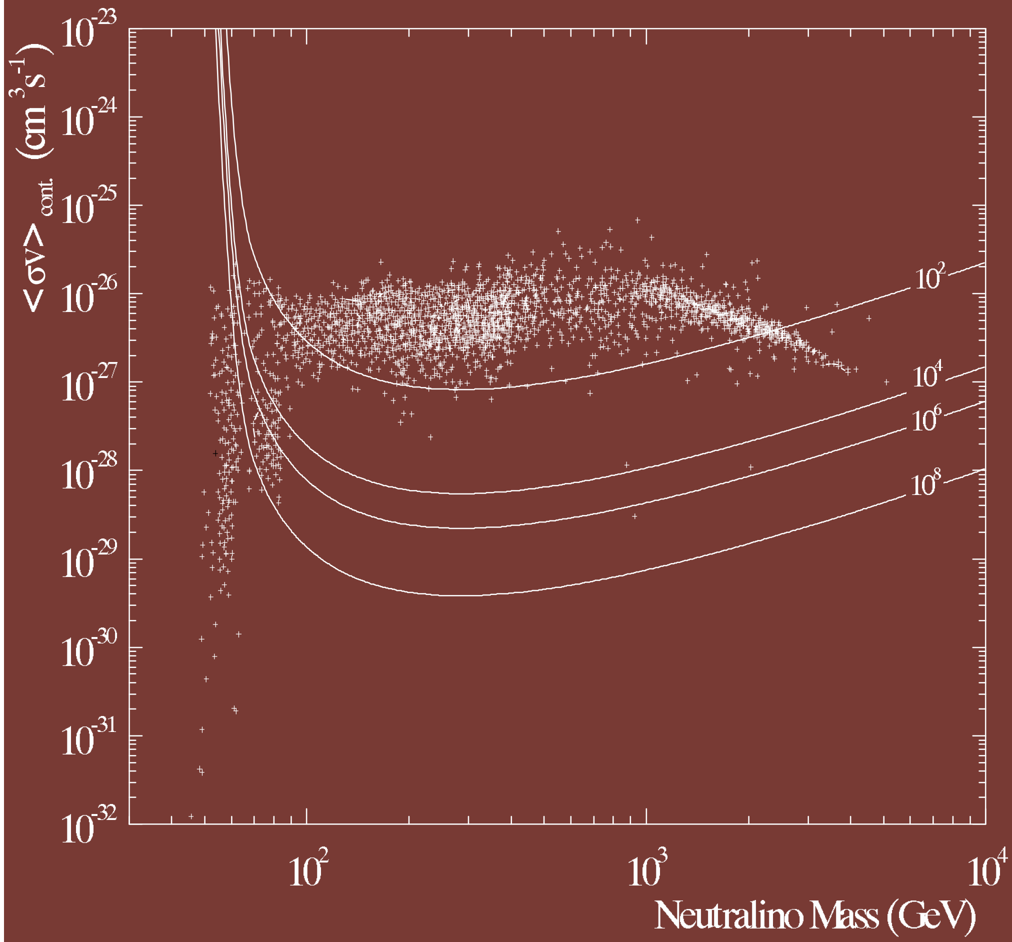
-continuum: $m_\chi \geq 65$ GeV

-line: $m_\chi \leq 4.5$ TeV

-detectable in both: 65 GeV $\leq m_\chi \leq$ 4.5 TeV (well….)

e.g., a 10^8 $M_\odot$ NFW *clump will be detectable in either the continuum* (77 GeV $\leq m_\chi \leq$ 5 TeV) *or the lines* ($m_\chi \leq$ 68 GeV) *but not in both (in principle, this can be used to extract info on the mass or density profile of the clump)*

Discussion: Combining Observations



-combine: the non-detectability of a $10^6\ M_\odot$ clump and the detectability of a $10^6\ M_\odot$ constrains considerably the SUSY p. space

Discussion

- Best case scenario with respect to:
  - (Perhaps) distance of the clump
  - (Perhaps) central concentration

- Worst case scenario with respect to:
  - Integration time
  - Backgrounds (high hadronic CR shower rejection: image shape, extent and intensity, directional info, UV content)

Conclusion

- DM *detectability in clumps:*

The chances of detecting clumps due to continuum γ-rays via upcoming ACTs are very good, especially in the case of relatively massive and highly centrally concentrated clumps. The signatures expected from the γγ- and Zγ-lines are less easily detectable, even though higher integration times can improve considerably their detectability.

Conclusion

- Constraining the SUSY parameter space:

If clumps are detected first, e.g., through their synchrotron emission or via GLAST, γ-ray studies with ACTs will help narrow considerably the SUSY parameter space. In most cases, it will be the non-detectability, rather than the γ-ray detectability of the otherwise detected, e.g., in synchrotron emission clump that will Impose the strongest constraints on the SUSY parameter space (will rule out the largest part). The lines will help lift degeneracies among the several SUSY models.